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POTATO STORAGE AND STORAGE HOUSES

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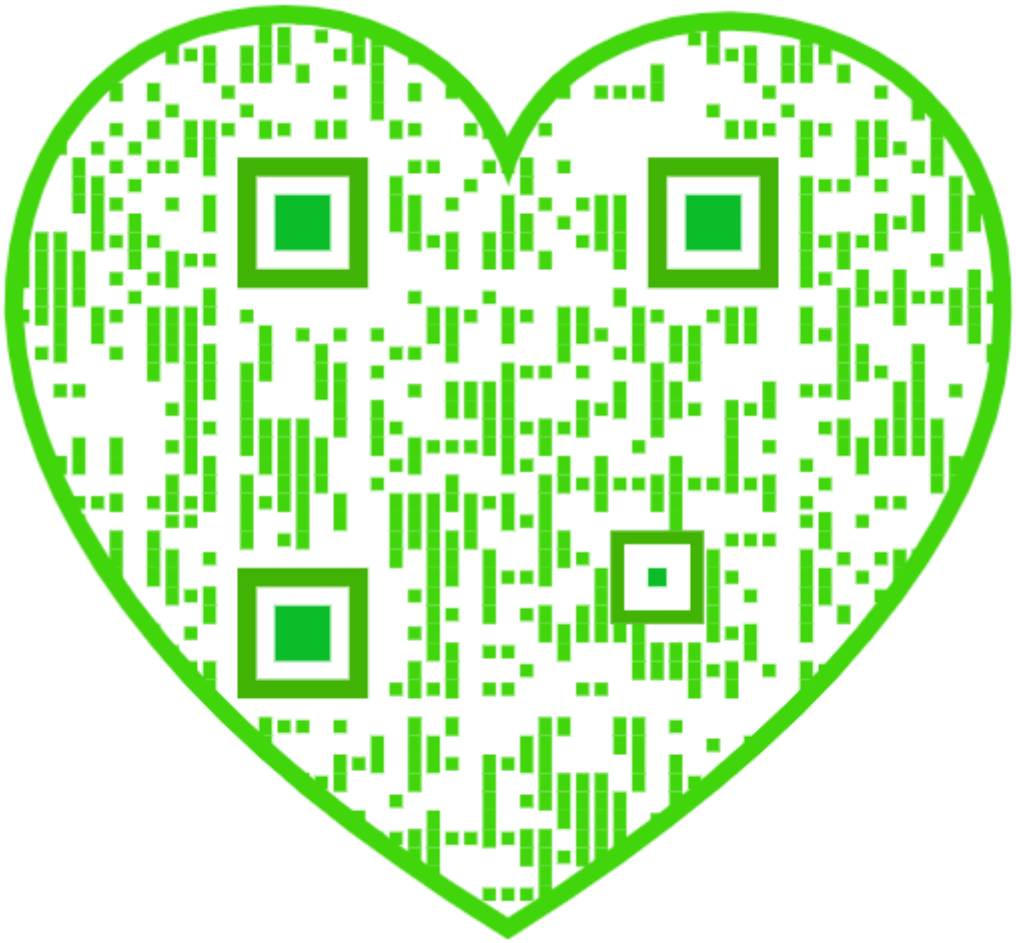

THE POTATO is one of the most important food crops in the United States, and storage has necessarily been utilized to a very considerable extent to hold over supplies for both seed and food purposes from one season to another.

When potatoes were plentiful and relatively cheap, little attention was given to such wastage and loss as usually occur in storage; in fact, a considerable loss was regarded as inevitable. In times of high prices and scarcity of supply the need of conserving the entire production for seed and food purposes is of the utmost importance.

Potato storage serves two purposes: It makes possible a longer marketing period for the crop, and it insures the minimum amount of loss from moisture and decay.

The successful storage of potatoes is dependent on a number of factors, including the quality of the tubers stored, the temperature at which they are held, the moisture content of the air, the size of the storage pile, and the exclusion of light. The proper storage temperature for potatoes is supposed to range from 38° to 40° F.

Careful investigations during several seasons have clearly demonstrated that losses in storage can be largely prevented by the proper construction and intelligent management of storage houses.

This bulletin deals with the fundamental factors of construction and management of storage houses, as well as with the methods of handling the crop that govern the condition of potatoes in storage.

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POTATO STORAGE AND STORAGE HOUSES

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INTRODUCTION

The comparative ease with which potatoes are ordinarily carried through the winter in the northern portion of the United States is largely responsible for the fact that until the last few years little serious study has been made regarding the most favorable conditions of storage for the preservation of seed and table stock potatoes. The quantity of potatoes stored annually is relatively large, but as yet little reliable data regarding the actual losses incurred from transpiration, respiration, and decay under different storage conditions are available. A recent publication [a] contains interesting information on storage losses.

OBJECT OF STORAGE

The primary object of storage is to hold a more or less perishable product in a salable and edible condition throughout as long a period as may be economically desirable. In the case of the potato, the storage of the late or main crop and of second-crop potatoes intended for winter or spring consumption or for seed purposes is of primary concern. The early or truck crop is usually sold as harvested, but there may be seasons when, owing to low prices, it might be found profitable to store the crop for a short period, or until such time as market conditions justify its disposal.

Good storage not only serves to hold perishable crops in a salable condition but insures also a more uniform market supply throughout the season. It should provide the proper conditions for preserving the natural quality of the potato for table purposes, and also should preserve its vigor for seed purposes.

The factors supplied by storage must be of such a character as to protect the tubers from extremes of cold and heat and from the light. Usually these are the only factors seriously considered in potato storage-house construction. Recent studies have shown that humidity, aeration, and the size of the storage pile or bin are important factors. They have also shown that there is a definite correla-

[a] Smith, Ora. Studies of Potato Storage. N. Y. (Cornell Univ.) Agr. Exp. Sta. Bul. 553, p. 1–57, 1933.

tion between temperature and humidity in the keeping quality of potatoes during the first two weeks of the storage period.

STORAGE TEMPERATURES

Storage-temperature studies by Peacock and Wright [1] have shown that the immediate subjection of newly harvested potatoes to low temperatures, 36° to 40° F., or even somewhat higher, is undesirable. Those investigators found that abrasions, cuts, and bruises of the surface of the tuber do not heal properly at temperatures below 50°, provided, of course, that the surface of the potato be cooled to this point. Below 50°, skin abrasions, cuts, and bruises turn dark and become shrunken underneath in proportion to the lowness of the temperature to which they are subjected. At temperatures of 32°

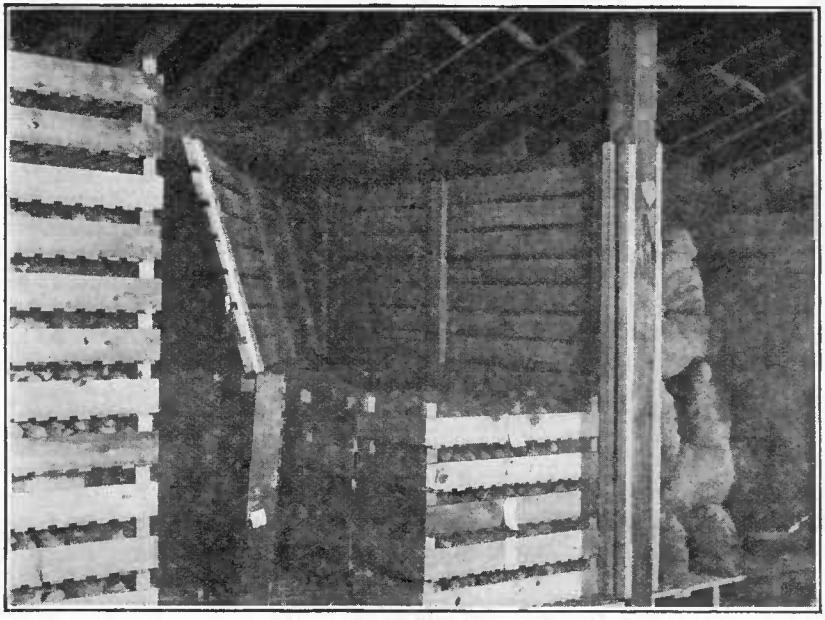

FIGURE 1.—Interior view of the former potato-storage cellar of the United States Department of Agriculture at Jerome, Idaho, showing ventilated division walls and floor and slat-bottomed flats for storing seed potatoes

to 36° an appreciable amount of tuber rot will develop in the injured areas. On the other hand, if newly harvested potatoes, especially those somewhat immature, are subjected to a temperature of about 60° for the first 10 days of their storage period in a relatively high humidity, the injured tissues of the potatoes will quickly heal over, provided the wound has not become infected with a disease organism. After this brief period of relatively high temperature of the storage house it should be gradually reduced to from 45° to 40°. This temperature will serve to hold potatoes in good condition for the first three or four months with good results, and after this period they should be held at a temperature between 38° and 40°.

[1] PEACOCK, W. M., and WRIGHT, R. C. LOW TEMPERATURE INJURY TO POTATOES WHEN STORED SHORTLY AFTER HARVEST. Proc. 13th Ann. Meeting Potato Assoc. Amer. (1926), p. 99–101. 1927.

It is not believed that lower temperatures are necessary or desirable if the depth of the potatoes in the bins is not too great and if suitable facilities for aerating the storage house have been provided. (Figs. 1 and 2.) The only exception to this statement would be in the case of the presence of certain Fusarium rots, which have been found to thrive at lower temperatures than most other potato tuber diseases. Investigations by the United States Department of Agriculture have demonstrated that these fungi are most effectively controlled at 40° to 38° F.

Careful investigations have shown that the freezing point of the potato lies between 29° and 28° F.

When it is remembered that the sole function of storage is to preserve the stored product in as nearly its original condition as possible, it would seem that the maximum temperature at which

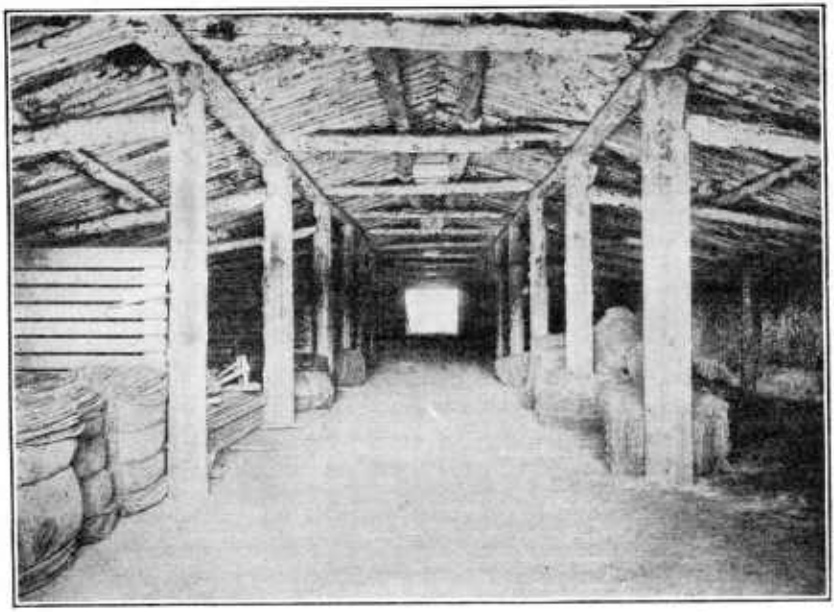

FIGURE 2.—Interior view of a potato-storage cellar at Carbondale, Colo., showing ventilated division wall, pole roof, and supporting timbers. (Courtesy of L. D. and F. E. Sweet)

tubers can be maintained firm and ungerminated and at the same time hold fungous diseases in check should be considered the most advantageous.

EFFECT OF STORAGE FACTORS

A clear understanding of the effect of storage factors upon the life processes and the quality of the product in storage is vital to their intelligent use. In the discussion of these factors, therefore, an attempt will be made to explain the effect of temperature, light, humidity, aeration, and size of pile or bin upon the stored product.

LOW STORAGE TEMPERATURES

It has long been recognized that when potato tubers have been subjected to a temperature below 40° F. for any considerable period

the flesh will have a sweetish taste when cooked. The degree of sweetness will be proportional to the lowness of the temperature and length of time the potatoes are held. Sugar accumulation may or may not be an objectionable feature, according to whether the tubers are to be used for table purposes immediately upon removal from storage. Studies by Appleman [2] have served to demonstrate that when such tubers are exposed to a temperature of 70° to 75° F. for a week about four-fifths of the sugar accumulation is removed. It is therefore apparent that while any considerable accumulation of sugar in the potato is undesirable, it does not necessarily constitute a permanent injury for table purposes.

LIGHT

Potatoes when exposed to strong or even modified light are soon materially injured for table purposes. Therefore, in order to preserve the table quality of potatoes, it is necessary to exclude all light from the storage house. The injury is due to the greening of the tubers and to the development of an alkaloid in the outer layer and chiefly around the eyes. This alkaloid is technically known as solanine and when present in sufficient amount it makes the consumption of such potatoes dangerous to the health of the consumer. Several deaths from eating badly greened potatoes have occurred in both man and animals.

Exposure to modified light, if the potatoes are kept cool and well aired, is not injurious to potatoes intended for seed purposes.

Whenever it is feasible the storage house should be lighted by electricity.

HUMIDITY

Experimental studies have demonstrated that a high degree of humidity is desirable in the potato-storage house. Until recently it was thought desirable to give ample ventilation during the first two or three weeks of the storage period, with a view to the rapid removal of the moisture given off by the stored stock in the regular process of transpiration. Present knowledge indicates that it is desirable to maintain relatively high humidity and temperature conditions during the first two or three weeks of storage. As previously stated, such conditions favor a more rapid healing over of abrasions or cuts resulting from the harvesting and handling of the tubers.

AERATION

In order to insure an ample supply of pure air in the storage house it is necessary to make generous provision for ventilation. The air intakes and outlets should be so arranged as to insure a rapid and even distribution of air throughout the structure. Recent studies have shown that a comparatively high humidity together with similar temperature conditions during the first 10 days or two weeks of the storage period is desirable. During this period little ventilation is advisable. Once the wounds and abrasions of the tubers have healed over, sufficient cold air should be admitted to remove excess moisture and reduce the temperature to from 45° to 40° F. This

[2] APPLEMAN, C. O. CHANGES IN IRISH POTATOES DURING STORAGE. Md. Agr. Exp. Sta. Bul. 167, p. 330. 1912.

temperature is sufficiently low for the first three or four months, after which a temperature of 38° to 40° should prove satisfactory.

SIZE OF STORAGE PILE OR BIN

It is not considered good practice to store potatoes in large bins or piles. Not infrequently potatoes are stored to a depth of 10 to 15 feet, with corresponding lateral dimensions. When stored in this manner immediately after harvesting they are almost certain to go through a rather violent sweating or curing process, during the course of which the tubers in the central portion of the pile are frequently subjected to a dangerously high temperature. This is especially true if the tubers are slightly immature, or were not dry and free from moist soil when gathered, or if stored when the outside temperature is high, making it difficult to lower the inside temperature of the house. Overheating from any of these causes may be avoided by making some provision for aerating the pile. This is most easily accomplished by inserting ventilated division walls or ventilating shafts at intervals throughout the bin. In storing potatoes, therefore, the desirability of good aeration should be kept in mind and the necessary provision made for insuring it.

TYPES OF STORAGE

Storage in its primitive stage consisted in burying in the soil the product to be preserved, or storing it in a cave or an excavated chamber of some sort. As wealth increased and agricultural industries expanded, better types of storage were developed, until to-day we have large, artificially refrigerated cold-storage plants in which the temperature of the various chambers can be maintained at any degree desired.

In the case of the potato, the simplest and most primitive form of storage is still practiced to a limited extent in some sections. While the house cellar is used occasionally for potato storage, its consideration in this bulletin is regarded as unnecessary. At the present time the types of storage may be designated as follows:

Pitting.
The dugout or potato-storage cellar.
The insulated wooden structure.
The Aroostook (Me.) type of storage house.
The artificially refrigerated storage house.

When deciding upon the type of storage house best suited to one's means the following factors should be considered: (1) The outside temperature and precipitation likely to occur during the storage period, (2) the character and cost of material involved, (3) the nature of the soil and drainage, and (4) the storage period.

It is self-evident that in the arid and semiarid regions of the West a materially different type of construction from that in use in the rain-belt section of the East could be adopted.

POTATO STORAGE-HOUSE CONSTRUCTION

In considering the construction of potato storage houses no attempt will be made to go into minute details regarding the actual building operations. It is hoped, however, that the various illustrations of plans and types of storage houses presented will suffice to convey the information necessary to a proper understanding of the essential features of construction of each type discussed.

PITTING

The simplest type of potato storage is that of pitting. To store potatoes successfully by this method it is necessary to have a well-drained site or one that can easily be provided with good drainage. To a large extent the term "pitting" is a misnomer, as the depth of the excavation is generally very slight, usually from practically nothing to 1 to 2 feet. The size and shape of the pit is of course governed to a large extent by the quantity to be stored and the severity of the weather. Where extremely low temperatures are likely to occur the pit may be two-thirds to three-fourths as broad as long, whereas under the opposite conditions it should not be over half as broad as long. It is never desirable to store too large a quantity of tubers in one pit, on account of the possibility of spread of disease. If an excavation of 6 inches to 1 foot has been made it is desirable to place a light layer of straw on the floor to insulate the

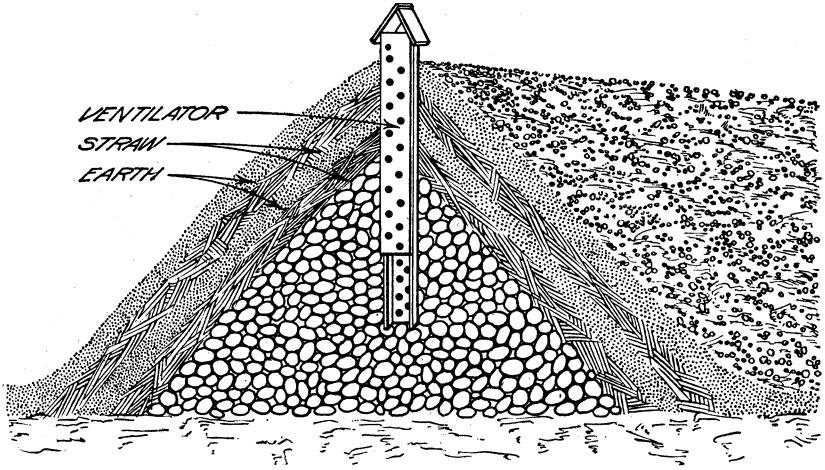

FIGURE 3.—Cross section of a potato pit insulated with layers of straw and earth, showing the perforated ventilator in position and the potatoes piled in inverted V-shaped fashion

potatoes from the soil. The tubers should be in a ridge or inverted V shape, as shown in Figure 3. When piled in this way the largest possible area of the pile is exposed to the air, and at the same time when covered the pile sheds rain better. Provision should be made for aeration when piling the potatoes (fig. 3), in order to allow the escape of moisture given off in respiration and transpiration.

The potatoes are best insulated against cold and heat by covering with alternate layers of straw and earth. The potato pile when completed should be covered at once with a layer of straw of sufficient depth to exclude light and at the same time to protect the tubers from frost. A light scattering of soil over the straw will serve to prevent its blowing off. Unless extreme cold weather sets in immediately, it is desirable to leave the pile in this condition for a week or 10 days in order to allow the escape of heat and moisture. The first covering of straw should be sufficient to provide a 6-inch layer when compacted by the soil. As the weather grows colder a layer of soil 4 to 6 inches deep should be added, or if rains threaten, soil should

be added to shed the rain. An additional layer of straw and soil should be added where moderate winter weather prevails, and even a third where subzero weather and light snowfalls are to be expected. This, of course, must be done before the ground freezes. Care must be taken to stop the ventilator openings with straw or other protective material during severely cold weather; otherwise loss from frost will be sure to occur.

The ventilator should be provided with a wooden cap in order to shed rain and snow. If the pit is longer than 10 feet, more than one ventilator should be provided. If the required attention is given to a pit of this sort, one can be reasonably certain that the tubers will keep in almost perfect condition until spring.

The chief objection to the pit is that the potatoes stored therein are not accessible during the winter.

THE DUGOUT OR STORAGE CELLAR

The dugout or cellar type of potato storage in some of its various forms of construction is probably more widely used than any other type. In the central and western portions of the United States it is practically the only kind of storage used. It is found in its most primitive state in the arid and semiarid regions of the West, where a low rainfall makes a water-tight roof unnecessary. As a rule the excavation for the cheaper structures of this type when erected on level or nearly level land does not exceed 3 feet in depth. The soil removed from such an excavation, particularly if the dugout is of any considerable size, is ample for banking the side and end walls and also for the roof. The cost of construction may be greatly modified, according to the character of the location.

Whenever possible the storage cellar should be located near the farm dwelling house, because in very cold weather it usually requires rather close attention to guard against the tubers being frosted. Where sidehills, knolls, or what are termed in the West "hogbacks," consisting of narrow and usually short ridges of land, are available, it is advisable to take advantage of them, because their use usually insures better drainage and a ground-level entrance at one or both ends of the building. Where these natural conditions of topography are not available and a central driveway is desired, it is necessary to construct an inclined driveway. When no wagon entrance is contemplated, provision is made for filling the cellar through openings in the roof, in which chutes are inserted to convey the tubers. (Fig. 4.) In this type of cellar a bulkhead entrance is provided in order to permit of easy access for the removal of the stored crop.

In the cheaper dugouts, where the soil is sufficiently firm and adhesive it serves for the walls, the roof being supported on plates resting on the soil and held together by boards or joists. (Fig. 5.) This form of construction involves a deeper excavation and a constant element of risk from a cave-in if heavy rains occur. A better type of construction is represented in Figure 2, in which rough posts are set at intervals along the earthen side walls, for the purpose of supporting the plates. These posts may be recessed into the earthen wall so as to present an even face (fig. 6), or they may be set out far enough to allow covering them with heavy wire netting, planking, or poles, and a heavy layer of straw (fig. 7).

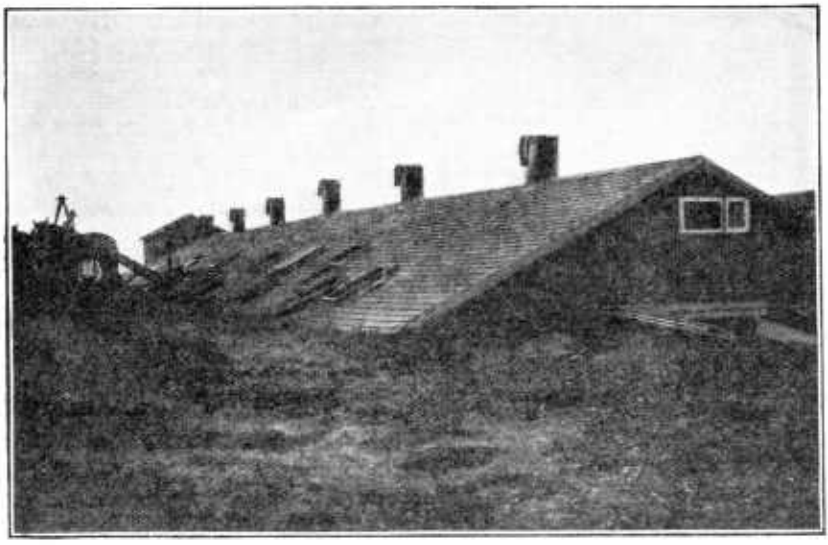

FIGURE 4.—A potato-storage cellar with water-tight roof, showing openings in the roof through which the tubers are spouted into the cellar. Sabin, Minn.

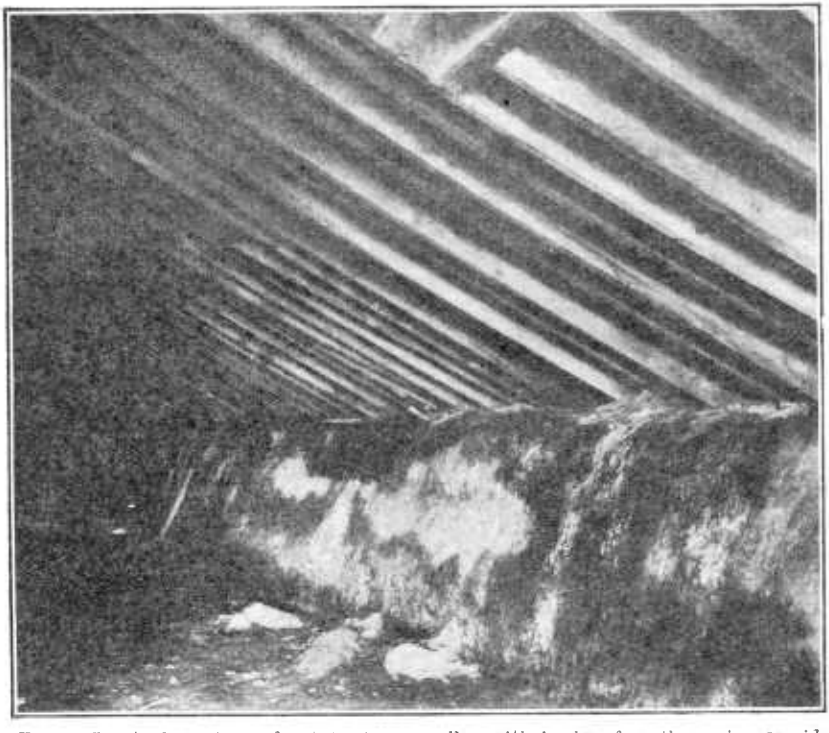

FIGURE 5.—A cheap type of potato-storage cellar with banks of earth serving as side and end walls, used in semiarid or irrigated sections. Greeley, Colo.

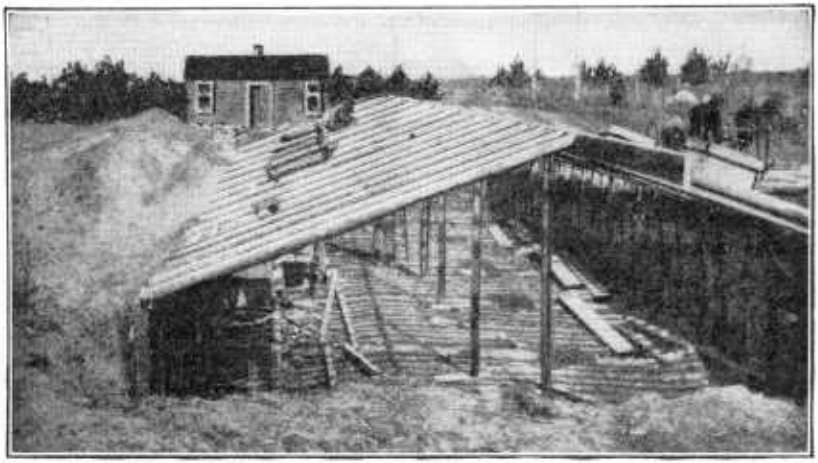

FIGURE 6.—A potato-storage house in course of construction, showing posts recessed in walls of earth and the method of placing ventilators in the roof. Jerome, Idaho

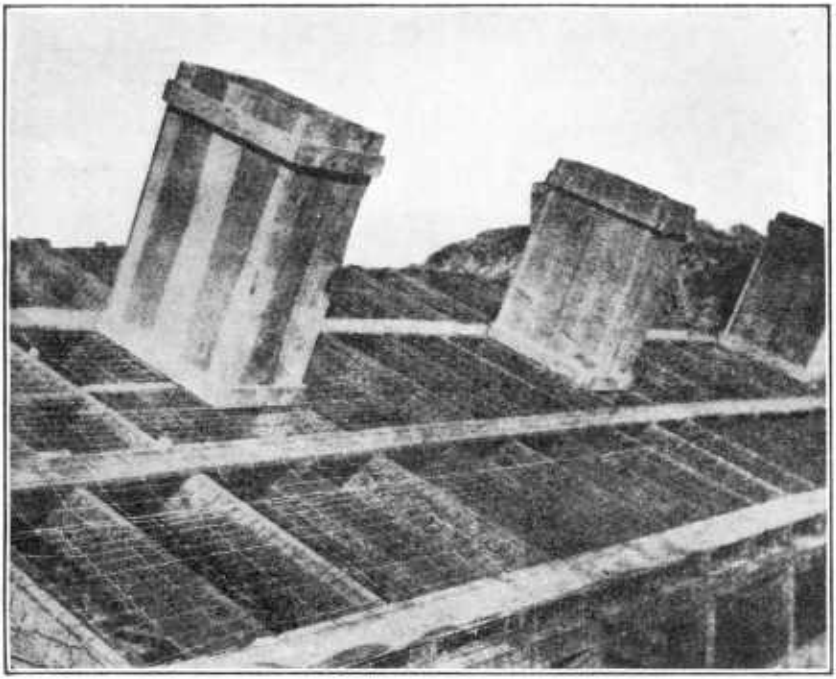

FIGURE 7.—A potato-storage cellar, showing side and roof framing covered with woven wire and with ventilators in place, ready for applying the layers of straw and earth. Aberdeen, Idaho

Where the surrounding area is level and there is danger from irrigation seepage, the storage house is built entirely above ground. In such cases, although the construction of the walls is practically the same as described in the preceding paragraph, the cost is increased on account of the greater quantity of soil to be handled to cover the roof and walls.

Another type of storage house, not infrequently encountered, in Colorado at least, is that of walls constructed with a tough sod such as that formed by flags or other wiry rooted plants. In this case the side and end walls, 2 feet or more in thickness, are constructed entirely of blocks of sod. (Fig. 8.) One of the most unusual storage houses observed in the course of these studies was seen in Utah. In this case both side and end walls were constructed with baled alfalfa hay.

In the more expensive and substantial structures the walls are built of stone or concrete. The material entering into the roof

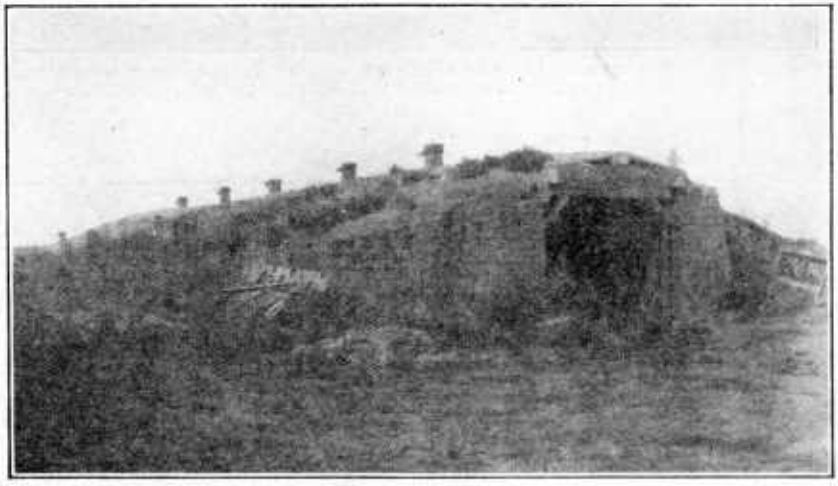

FIGURE 8.—A potato-storage house with walls of sod, adapted only to dry sections

construction of the dugout or cellar storage house in the region under discussion frequently consists of unsawed lumber. In such cases rafters are cut from small trees. (Figs. 2, 6, and 9.) The whole roof may be covered with poles (fig. 2) and the poles covered with a heavy layer of straw and 6 to 8 inches of soil, or the rafters may be covered with heavy woven-wire fencing material (figs. 7 and 9) and then with straw and soil.

In regions where the normal rainfall is sufficiently heavy to render straw and soil roofs undesirable, the storage cellar is constructed with a water-tight roof. Usually the roof is covered with rough lumber and building paper and then shingled. Occasionally it is sheathed with matched lumber on the inside. This construction provides a fairly well insulated roof that requires but little further protection except in protracted spells of cold weather, when it is advisable to apply a layer of straw or strawy manure. A combination of straw and earth and a superimposed water-tight roof (fig. 10),

although more expensive, is an ideal method of roof construction. An allowance of a 6-inch air space between the dirt roof and the

FIGURE 9.—Interior view of a potato-storage cellar with side and end walls of stone, showing the type of roof construction used. Greeley, Colo.

water-tight roof preserves the latter from decay and at the same time has a considerable influence as a nonconductor of heat. Some authorities consider this a well-justified expenditure of money.

FIGURE 10.—Dugout potato-storage cellar with straw and soil roof and superimposed water-tight roof. Greeley, Colo.

The roof type of the western potato cellar, whether it is similar to that shown in Figure 4 or in Figure 10, is admirably adapted to

storage in the middle-western and northeastern portions of the United States, wherever good drainage can be obtained.

Entrance way.—The entrance to the storage cellar, whether for team or man, should be provided with two sets of doors. The vestibule or bulkhead entrance is a convenient one, and provides good protection against cold or heat. (Figs. 11 and 12.)

Ventilators.—Provision should be made in all dugouts or storage cellars for generous ventilation. Such provision is well shown in Figures 4, 6, 8, 10, 11, and 12, and in the title-page illustration. Several styles of ventilators are shown, and it is largely a question of preference on the part of the builder as to which type is selected.

A ventilator should be so constructed that the opening at the top is protected by a cap, which may be rigid or hinged. It should extend through the roof into the cellar far enough to permit the insertion of a swivel damper operated by a spring or lever, or with a slide damper that can be opened or closed at will. The ventilator

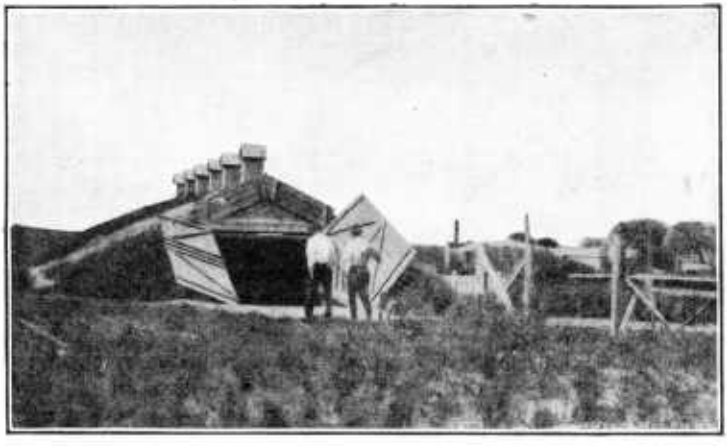

FIGURE 11.—A potato-storage cellar, showing a bulkhead driveway entrance in which the grade into the cellar is provided inside the entry to the bulkhead. Jerome, Idaho

should be of sufficient size, about 12 by 18 inches, to admit a reasonable volume of cool air and facilitate the egress of warm air.

Lighting.—While the total exclusion of light is an essential feature of the construction of a good potato-storage house, some light is necessary during the winter when workmen are engaged in sorting and preparing stock for market or for seed purposes. Usually no provision is made for lighting the storage house by natural light, except that which may filter through the ventilator shafts when the caps are removed or which may be obtained by opening doors. This method can be employed only when the outside temperature is sufficiently high to prevent chilling or freezing the potatoes near the openings. In some storage houses the ventilators are large enough to permit of a hinged window in the shaft which serves to admit light when desired without running any risk of injury to potatoes immediately below. While such a system of lighting may be adequate for the area immediately below the shaft or near the open door, it does not provide a satisfactory lighting system, and reliance must still be placed in a lantern or a lamp.

The potato-storage houses constructed and operated by the United States Department of Agriculture at Greeley, Colo., and Presque Isle, Me., are electrically lighted, and wherever electricity is available this method of lighting is urged upon those contemplating the erection of a house. The cost of installation, wiring, and fixtures is comparatively slight, and the advantages of an electrically lighted storage house are out of all proportion to its cost.

A description of the materials entering into the construction of some of the better-grade dugouts will be found in the accompanying plans prepared for the erection of a storage cellar on the Sweet ranch at Carbondale, Colo., and in those prepared for the storage cellar at Jerome, Idaho. (Figs. 13, 14; see also figs. 19 and 20.)

Interior arrangement.—The interior arrangement of the storage cellar is governed very largely by its size and character. Where

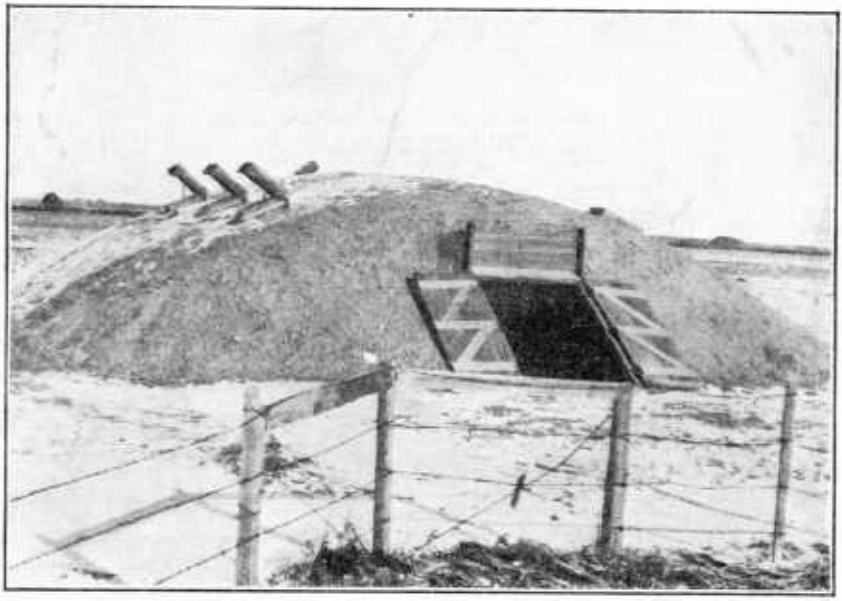

FIGURE 12.—The potato-storage house shown in Figure 7, with the covering of straw and earth in place. Note the bulkhead entrance and the hinged ventilator caps. (Courtesy of L. C. Aicher)

no driveway entrance is provided and the house is narrow, say 12 to 20 feet in width, the entire space is used for storage purposes. The dirt floor of the cellar may be left uncovered or it may be floored over with rough lumber; in some cases it is cemented.

In most of the better types of houses in which there is a central driveway with bins on either side, the driveway is an earthen one, but the storage bins have ventilated wooden floors laid on joists. The joists, being at right angles to the drive, provide an open space between the floor and the earth beneath, and this, as will be seen later, furnishes an unrestricted circulation of air beneath the bins. (Fig. 1.) Where posts are used in the construction of the walls and are covered with woven wire on the outer surface, the inner surface of the post should be covered with 3-inch board strips, allowing a 1-inch space between the boards. This type of construction provides

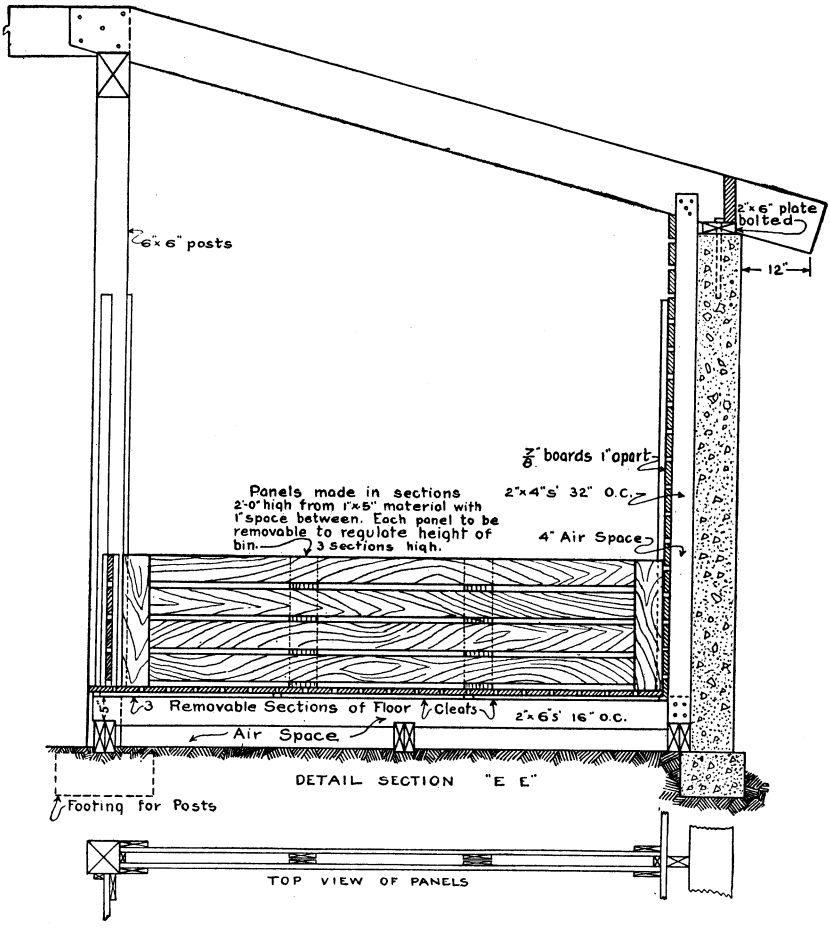
2"x 6" plate bolted
6"x 6" posts
12"
⅞" boards 1" apart
Panels made in sections 2'-0" high from 1"x5" material with 1" space between. Each panel to be removable to regulate height of bin.
3 Sections high.
2"x4"s 32" O.C.
4" Air Space
3 Removable Sections of Floor
Cleats
2"x6"s 16" O.C.
Air Space
DETAIL SECTION "E E"
Footing for Posts
TOP VIEW OF PANELS

FIGURE 13.—Section of one side of a potato-storage cellar, showing the method of constructing the aerated bin. Jerome, Idaho

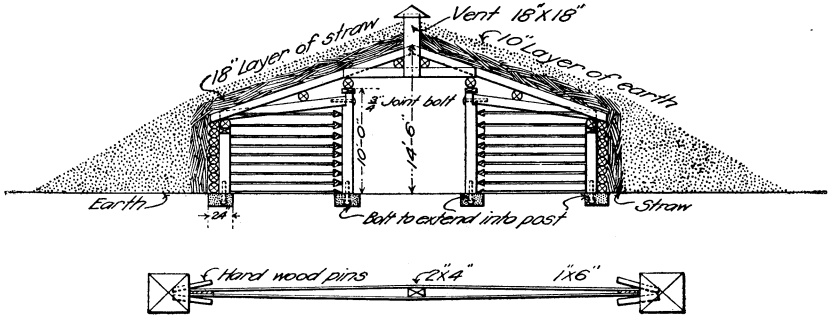

FIGURE 14.—Cross section of end elevation of potato-storage cellar at Carbondale, Colo., and top view of ventilated partition

a conduit for air on the side wall and, connecting with the bottom, affords an air passageway completely around the stored tubers. In storage cellars having an interior width of 30 feet and a length of 50 or more feet the central driveway need not be over 9 or 10 feet in width, with five storage bins on each side of the drive. These units of width seem desirable, because this is a convenient distance at which to set the purlin supports.

The division walls may be constructed after plans shown in Figure 13 or they may follow those shown in Figure 14. In any event the division walls should be double, with an air space between the boards. The front wall is constructed in sections similar to those of the partition walls, but of heavier material, because it is only a single wall. This type of bin construction very materially lessens the danger from tuber heating in storage and provides a convenient and sanitary bin which can be taken down easily and disinfected when desired.

FIGURE 15.—An insulated frame potato-storage house used for storing second-crop potatoes. Morrill, Tex.

THE INSULATED FRAME STRUCTURE

The insulated frame potato-storage house is not used very extensively and as a rule is better adapted to southern than to northern conditions. The construction feature of such a storage house is the thorough insulation of its walls, ceiling, doors, and windows. (Figs. 15 and 16.) The type of house described in Farmers' Bulletin No. 1442, Storage of Sweetpotatoes, will serve equally well for the potato, but in the case of the latter no artificial heat will be required ordinarily unless the outside temperature when harvesting the late crop is below 50° F. Facilities for heating storage houses of the type under discussion, in the North at least, must be provided for extremely cold weather. This is usually accomplished by means of an ordinary heating stove.

Storage houses of this sort are not to be recommended for northern localities, nor is this type advocated for the South except where poor drainage conditions will not permit the use of the dugout or cellar style of house. It is not recommended because it can not be so economically constructed, nor does it furnish so good a type of storage as the properly ventilated cellar storage house.

THE AROOSTOOK TYPE OF STORAGE HOUSE

The Aroostook type of storage house, with concrete or masonry basement walls and wooden superstructure, seems to be distinctly a

product of Maine, and so far as has been observed it is not found to any extent outside that State. It is an expensively constructed house and is almost always located on a sidehill or knoll in order that advantage may be taken of a ground-level entrance. Few if any of these storage houses have both front and rear entrances on the same ground level, but practically all of them have a rear ground-level basement driveway and a front ground-level entrance to the wooden superstructure. When the rear entrance is located in the end (fig. 17), the basement is usually divided into a number of bins on either side of the driveway. The floor may or may not be of cement. Usually those storage houses that have cement floors, as well as those that have not, are provided with wooden floors somewhat similar in construction to those shown in Figure 1.

The basements of the Aroostook or Maine type of storage houses

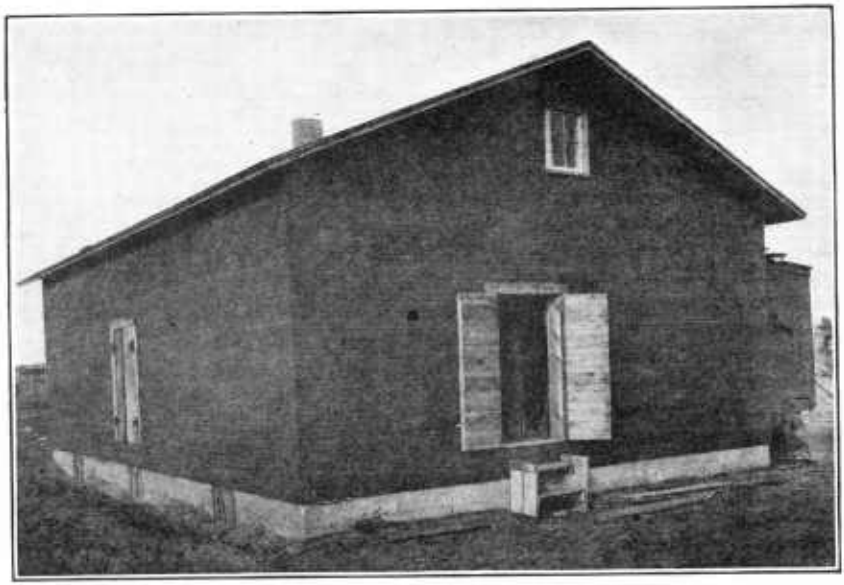

FIGURE 16.—An insulated frame potato-storage house with a cellar. Greenville, Mich.

are usually from 8 to 12 feet or more in depth, and most of them have a capacity of several thousand barrels. As a rule the only provision made for ventilation of the basement is by means of trapdoors in the floor above, through which the filling of the bins is completed. Of late some of the newly constructed storage houses have large metal ventilators inserted along the ridge of the roof, the longer houses having two or more of these ventilators with weather-vane caps. In addition to serving a useful purpose in filling the bins and protecting the potatoes from inclement weather, the wooden superstructure may be used for the housing of farm implements, sacks, barrels, or crates, and even in some cases hay or grain.

The house shown in Figure 17 is representative of this type and gives a fairly accurate conception of the style of its exterior construction. That such houses have proved satisfactory to the potato

grower in Maine is evident from the fact that practically no other style of potato-storage house is in use there. It is not conceivable, however, that they will ever supersede the dugout or storage cellar now so extensively used in the Middle and far Western States, and it is not at all probable that the latter will ever supersede the Aroostook type in Maine. Both have distinctive features that peculiarly adapt them to their own environment but do not necessarily preclude their use in other localities.

THE ARTIFICIALLY REFRIGERATED STORAGE HOUSE

The present use of the artificially refrigerated storage house is confined very largely to the holding of either locally grown or

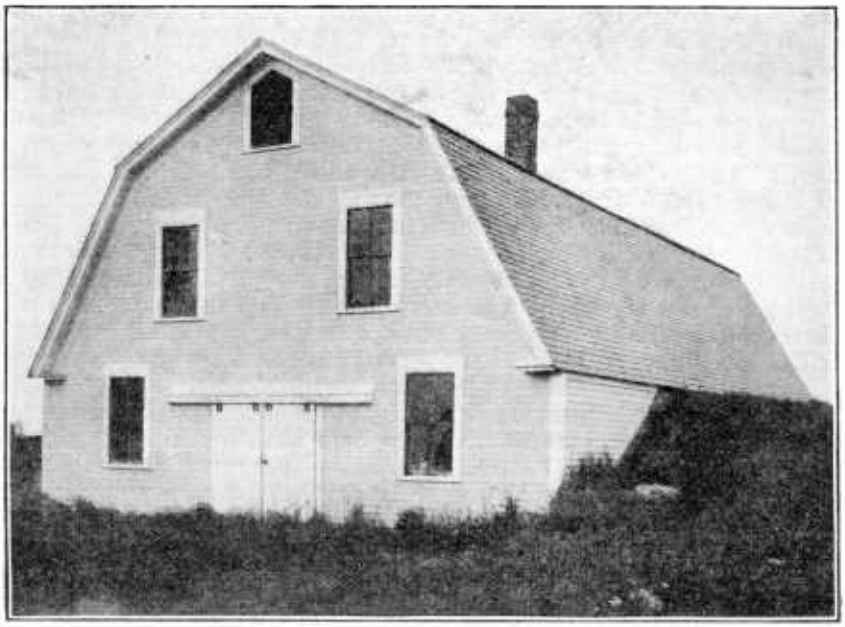

FIGURE 17.—A potato-storage house in Maine, showing a central driveway entrance into the lower or basement portion. The end entrance is more commonly used than the side entrance, especially in the larger structures

northern-grown seed potatoes for second-crop planting. For example, in New Jersey second-crop home-grown seed or northern-grown seed is put in cold storage about the last of March or the first of April and held there until the latter part of July, when it is removed and allowed to warm up for a week or two before being planted. A similar use of cold storage is also made by growers in other localities producing second-crop potatoes.

The only other use of cold storage of any considerable importance is that of storing fall shipments of northern-grown seed potatoes in transit to southern points. For example, a considerable quantity of western Nebraska Triumph seed potatoes when shipped in the late fall to Louisiana or adjacent States is held at Kansas City, Mo., until near the time of planting in the section to which it is consigned. Such use of storage-in-transit privileges permits an

earlier shipment of the seed stock and an avoidance on the part of the shipper of undue risk from chilling or freezing when it is moved from cold regions in midwinter.

In the northern potato-growing sections there is practically no need of an artificially refrigerated storage house, because in properly constructed, naturally cooled storage houses potatoes may be kept in excellent condition throughout their normal storage period. The only possible additional use for a cold-storage house is in commercial early potato-producing centers, such, for example, as Hastings, Fla.; Charleston, S. C.; Norfolk and Cape Charles, Va. In these localities it would be possible for the growers or a cooperative organization of growers to purchase their supply of northern-grown seed potatoes on a fall-delivery basis. Usually the northern grower or seed dealer makes a difference in price between fall and winter delivery of at least 50 cents a sack. This difference in purchase price would practically offset the cost of cold-storing and handling the potatoes at their point of consumption. The adoption of such a practice would permit the shipment of the stock before severe cold set in and would remove the possibility of freezing, chilling, or overheating of the seed when in transit in midwinter. In the Hastings (Fla.) district it frequently happens that the grower has to hold his winter shipments for two or three weeks after their arrival and as a rule has no place in which to store his seed stock. As a result of this lack of storage facilities the sacks of seed are piled outdoors subject to the climatic conditions that may prevail at that time. On more than one occasion the seed stock has been seriously injured from frost and heavy financial loss has resulted. Such losses would be largely eliminated if a cold-storage plant were available.

An erroneous impression has heretofore prevailed in regard to the proper temperature at which to hold potatoes in cold storage. Temperatures of from 32° to 34° F. have been considered desirable. As a matter of fact during the early part of the storage period, or throughout the dormant or rest period of the potatoes, they can be held at a temperature of 45° with better results than at lower temperatures, so far as the vitality of the seed is concerned. With the passing of the rest period the temperature should be lowered to 40° to 38°. Whatever temperature is low enough to prevent undue sprouting is the most desirable one to use.

COST OF CONSTRUCTION

Owing to the wide variation in the cost of building material and in the price of labor in different parts of the country, a discussion of the cost of constructing any particular type of house must of necessity be more or less general in character.

The type and size of the house is in a large measure determined by the character of material available, the climatic conditions, and the storage capacity required. In determining the size of a storage house necessary to take care of a given quantity of potatoes the estimate should be based on 40 pounds per cubic foot of actual storage space, keeping in mind, of course, that potatoes should not be piled at too great a depth. On this basis a storage bin 10 feet square filled to a depth of 6 feet would hold approximately 400 bushels, or an average of 4 bushels to each square foot of floor space occupied.

In order to give some idea as to the relative cost of constructing the various types of storage houses that have been described, data have been obtained from practical potato growers who have erected storage houses or cellars of their own.

The first data presented pertain to the cost of the potato-storage cellar shown in Figure 2. The capacity of this cellar was stated to be 13,000 to 25,000 bushels, and its cost is estimated at $1,000. In submitting the construction cost of this house it was explained that no charge had been made for the lumber used. It would seem, therefore, that the actual cost was at least $300 more, or a total of $1,300. On this basis the initial cost of providing storage for 1 bushel of potatoes ranged from 5.2 to 10 cents a bushel, depending on the depth to which the tubers are piled. Assuming, however, that the average life of such a potato-storage house is about 10 years, the actual storage cost, reduced to an average annual basis, is from 0.52 cent to 1 cent a bushel. These figures are somewhat lower than those presented by other investigators, who state that the first cost of storage in an average grade of potato cellar is about 20 cents a hundredweight or 1.2 cents a bushel a year on a 10-year basis. They further state that the first cost of storage in a cellar constructed without much regard to permanence and by the utilization of farm labor might be as low as 7 cents a hundredweight.

The following data are submitted by a Minnesota potato grower relative to the storage cellar shown in Figure 4: The size of the house is 20 by 100 feet, constructed with wooden walls and a watertight roof. The floor is 4½ feet below ground, and the walls extend 4 feet above ground. The house has a storage capacity of 12,000 bushels when piled 8 feet deep. Figuring the storage capacity of this house on the basis of 40 pounds per cubic foot gives an actual storage capacity of 10,666 bushels. This house was constructed at a cost of $1,200, or an average initial cost of 11.25 cents per bushel, or 1.125 cents on a 10-year basis. The storage house under discussion is provided with ventilators in the roof spaced 10 feet apart and has two lines of openings in the roof for the admission of potatoes. It does not have a driveway entrance but is provided with a bulkhead entrance at each end. The roof is protected from severe cold by a covering of straw or strawy manure. The inside temperature during such periods is taken by lowering thermometers suspended by strings through the ventilator shafts.

A grower at Caribou, Me., reported on the construction of a storage house 40 by 60 feet in size having a capacity of 4,500 to 5,500 bushels. The cost was $3,500, or an initial cost of from 64 to 82 cents per bushel. In determining the average annual bushel cost the greater durability of the house must be considered. A term of 30 years could easily be counted on for this type of construction, and this would greatly lessen the average annual storage cost per bushel.

In 1914 the Bureau of Plant Industry of the United States Department of Agriculture erected at Jerome, Idaho, the potato-storage cellar shown in Figures 1 and 18. The floor dimensions of the structure are 30 by 50 feet, with concrete walls 8 feet in height and 8 inches thick with a 12-inch footing. The even-span roof is of wooden-frame construction, over which is stretched heavy woven-wire netting similar to that shown in Figure 7. The netting is

covered with a heavy layer of straw, over which is placed a layer of soil sufficient to shed the usual rainfall of that section. Being constructed for experimental purposes, the interior arrangement, as will be observed by reference to the detailed building plan shown in Figure 19, differs somewhat from that of the ordinary potato-storage cellar in that it is provided with inspection and disinfecting rooms. These rooms are practically 9 by 9 feet in actual floor dimensions and are constructed with insulated wooden walls. Each room is provided with a window and with ventilation. The disinfecting room is so constructed as to be practically air-tight, thereby permitting the use of gas fumigation if desired.

The remaining part of the cellar is divided into eight bins, four on each side of the driveway, each approximately 10 by 10 feet. The floor of each bin is removable, being constructed in three sections, each consisting of 3-inch strips of ⅞-inch lumber spaced 1 inch apart, nailed to cleats and supported by 2 by 6 inch joists, which

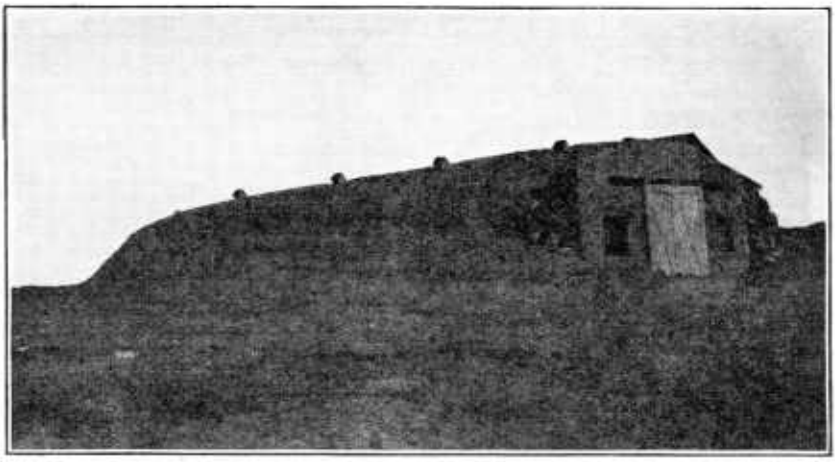

FIGURE 18.—Former potato-storage cellar of the U. S. Department of Agriculture at Jerome, Idaho, showing end entrance and arrangement of ventilators

in turn rest on three 6 by 6 inch sills. The 2 by 6 inch joists were given a 1-inch shoulder on the supporting sills, thus providing a 5-inch opening into the driveway and in reality placing the ventilated board-slat floor approximately 11 inches above the earthen one. The interior face of the concrete side and end walls of the storage cellar proper is furred with 2 by 4 inch studding spiked to the 6 by 6 inch sill below and to the rafter above. The studding is spaced 32 inches apart in the clear and is covered to a height of 6 feet with 4-inch board strips spaced 1 inch apart, as shown in Figure 13. The slatted division walls of each bin are double, constructed in sections similar to those of the floor, and are attached at each end to the supporting posts. The cleats on which the slats are nailed, coming opposite to each other when in place, insure a 1¾-inch air space between the division walls. This type of construction affords a complete circulation of air around each bin. A cross section of the end elevation of this storage cellar is shown in Figure 20.

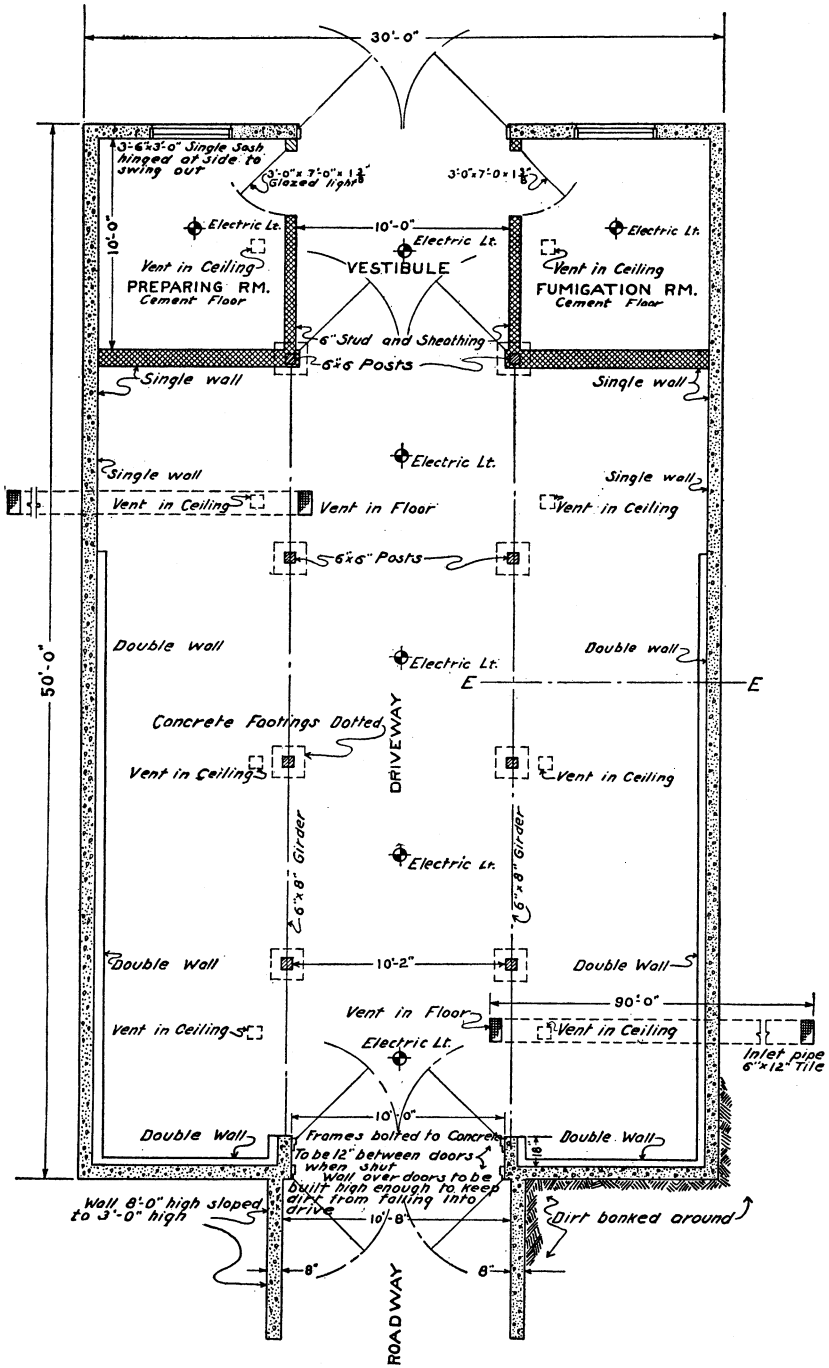

FIGURE 19.—Ground plan of the potato-storage cellar at Jerome, Idaho

The contract price for the construction of this storage house, including the electric-light wiring but exclusive of excavating and of the straw and dirt cover, was $1,340. A storage house 30 by 50 feet without inspection or disinfecting room could probably be built by a grower prepared to do most of the work himself for from $700 to $1,000.

SUMMARY

Storage is employed generally for the purpose of prolonging the season of food products.

The best storage temperature for table or seed potatoes is one that is high enough, for the first two weeks at least, to permit of suberization of wound injuries, after which it should not be any lower than necessary to inhibit germination and prevent undue loss of moisture.

The humidity content of the air of the storage cellar plays an important rôle in the proper healing over of wounds and in conserving moisture losses. The moisture content of the air should not be so high as to deposit a moisture film on the surface of the tubers

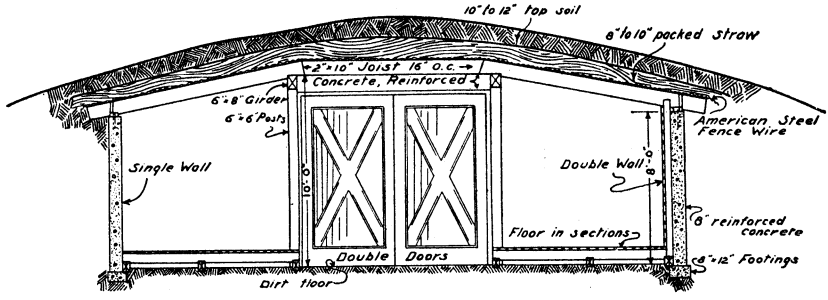

FIGURE 20.—Cross section of the end elevation of a potato-storage cellar at Jerome, Idaho

nor so low as to cause an unnecessary loss of moisture through transpiration.

Thorough aeration of the stored tubers is essential for the best preservation of seed stock and the reduction of storage losses.

The exclusion of light from the storage house is an essential factor in the storage of table stock.

Good storage is a vital factor in maintaining the vigor of seed stock. Its value is not yet fully recognized by the grower.

The simplest method of storing potatoes is pitting them. The next simplest form of storage is the dugout or storage cellar. The third type is the insulated wooden storage house, frequently found in the South. The fourth or Maine type is distinctively a Maine development and, aside from the artificially refrigerated storage house, is the most expensive.

The artificially refrigerated storage house is not practicable for farm storage, but is believed to have a place in the cooperative storage of potatoes in certain localities.

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